

Study of Artificial Financial Markets with Adaptive Trading Agents

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The Problem: The project aims to study various ways of designing intelligent trading and market-making agents. We will then study the cooperative and competitive behavior of agents under a previously developed artificial financial market environment. This research will give insights for designing general-purpose artificial markets and trading agents.

Motivation: In the past years, we and others have developed some basic families of algorithmic components for coping with multiple aspects of learning. It is natural to probe directly into the evolution of intelligence and learning mechanisms and into the problem of distributed intelligence such as collective learning, coordination and competition. In this project, we focus on an agent-based modeling of artificial markets: how software agents endowed with learning abilities might interact, co-evolve, and cooperate in *societies of learning agents*.

Previous Work: The project draws on at least three distinct subfields: market microstructure, experimental markets, and simulated markets. Studies in market microstructure theory provide important background and context for the experiments and simulations[6]. An alternative to the theoretical approach is an experimental one in which individuals are placed in a controlled market setting, given certain endowments of securities and cash, and allowed to trade with each other[2, 5]. Lastly, computer simulations of markets populated by software agents extend the experimental approach by allowing the experimenter to test various theories of learning behavior and market microstructure in a controlled environment[4, 3].

Approach: Our proposed research consists of three complementary parts:

1. **Artificial Market Dynamics** — Construction of *artificial financial markets* with adaptive trading and market-making agents whose behavior and performance are studied.
2. **Theoretical and Computational Studies of Market Equilibrium** — Study of theoretical reasoning related to market equilibrium.
3. **Web Market Design** — Improvement of the web market design to create a robust infrastructure on the Web which will be used as a control laboratory for human-based and for human+software-agent-based experiments, and as a teaching tool in classrooms.

In **Artificial Market Dynamics**, we have constructed various simulations to study (a) the efficiency of information aggregation and dissemination in a market, and (b) performance and characteristics of automated market-making strategies. In the study of information aggregation and dissemination, we have tried trading agents with identical, and heterogeneous preferences[1]. The results show that our trading agents can accurately infer and aggregate diverse pieces of information in many circumstances, and they have difficulties in cases where human traders are also unable to determine the rational expectations equilibrium.

For **Theoretical and Computational Studies of Market Equilibrium**, we will use artificial markets with software agents to simulate market equilibrium. There are many trading strategies that we can design, and we will study how the market equilibrium emerges and how this relates to individual preferences.

For the **Web Market**, our main goal is to provide a test bed for conducting large scale market experiments involving both human and artificial traders and market makers. The Web Market is an Internet-based electronic market which is designed to fully automate the trading process.

Impact: This research can provide insights for designing general-purpose markets and how they work from different points of view. The questions we ask in this project lie at the intersection of several disciplines, from computer science (distributed systems of agents), to learning (which is a key aspect of the artificial agents and possibly also of the market structure), to economics (financial markets are the primary focus), to cognitive sciences (interaction between agents' biases and properties with the overall behavior of the market).

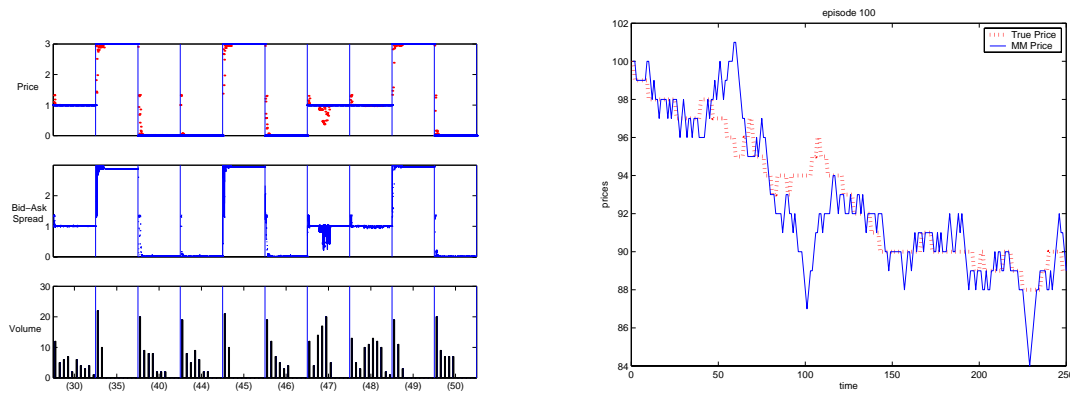


Figure 1: (a) Typical Realization of Artificial Markets Experiments (Information Dissemination with Identical Preferences). (b) Typical Realization of Market-Making using Reinforcement Learning (Episode 100)

Future Work: In the next phase of the project, we will carry out two distinct studies.

1. **Artificial Market Dynamics** — We will conduct further investigations in more sophisticated learning algorithms for our agents and the dynamics created by heterogeneous preferences. In the long term we are looking into the stability and evolutionary dynamics of different learning strategies in societies of agents. Additionally, we will try our adaptive market-making strategies in more realistic and complex market environments, and study the possible refinement of learning techniques to deal with such complex environments.
2. **Theoretical and Computational Studies of Market Equilibrium** — We will try to find a theoretical and computational explanation of relationships between the market equilibrium and traders' heterogeneous preferences.

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